Four Nitrogen Levels and Three Water Management Systems on Rice Yield and Nitrogen Recovery[1,2]

Rafael F. Olmeda and Fernando Abruña[3]

ABSTRACT

The permanently flooded, and the dry seeded and afterwards permanently flooded treatments produced higher grain yield than intermittent flooding treatments at all nitrogen levels. Rice responded up to 125 kg N/ha irrespective of the water management system. Recovery of applied nitrogen was higher when permanently flooded. The largest proportion of extracted nitrogen occurred in the stems and the lowest in the roots. Flowering was delayed 12 days in the intermittent flooding system at all nitrogen levels as compared to the other two irrigation management systems.

INTRODUCTION

Nitrogen and water determine high yields in rice (*Oryza sativa L.*) Water affects the nutrient level of the soil, the emergence of the rice plants and the growth of weeds. The effectiveness of nitrogen can be modified by the method of application, irrigation management system, season of the year, amount of water applied, straw management and pest control (3, 5, 6, 9, 13).

Because of the diversity of soil types, climatic factors and economic behavior, several planting and water mangement systems have been developed in the world for rice production. The most common systems are a) water-seeded on permanently flooded fields; b) dry-seeded and flooded intermittently afterwards; c) rain fed; and d) dry-seeded and flooded after the application of the post-emergence herbicide. Research (2, 4, 7, 14) has shown that high yields are obtained when the soil is saturated or flooded.

The amount of nitrogen applied determines yields. Grain yields decrease when nitrogen fertilization is not enough, whereas excess of nitrogen can induce lodging, delay maturity, affect grain quality and increase disease susceptibility (5, 6, 8).

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[2] Based in part on a thesis submitted to the Graduate School in partial fulfillment of the requirements for the degree of Master of Science in Agronomy, Mayagüez Campus, University of Puerto Rico.

This paper covers work carried out cooperatively between Agricultural Research Service, USDA and the Agricultural Experiment Station, College of Agricultural Sciences, Mayagüez Campus, University of Puerto Rico.

[3] Former Graduate Student, now rice specialist of Agricultural Extension Service and Soil Scientist, Agricultural Research Service, USDA.

The study reported was designed to determine the interaction between different water management systems and nitrogen levels in rice production and utilization of fertilizer nitrogen.

MATERIALS AND METHODS

The experiment was carried out at the Gurabo Research and Development Center at an elevation of about 50 m above sea level. Annual rainfall is about 1,500 mm, with a fairly dry season in winter and a rainy season from August through November. Average annual temperature is about 25° C, with a mean monthly variation of about 5° C. The solar radiation is 435 langleys/day.

The soil is a Coloso silty clay (Aeric Tropic Fluvaquents) with a pH of 6.8, bulk density of 1.35 g/cm^3, wilting point 15.20%, and field capacity 25.10% in the upper 15 cm.

The water management systems compared were 1) dry-seeded and permanently flooded 3 weeks after planting; 2) pregerminated rice seeded in permanently flooded field until 2 weeks before harvest; and 3) dry-seeded and flooded intermittently afterwards (4 cm of water weekly).

In combination with the irrigation systems, four nitrogen levels as ammonium sulfate $(NH_4)_2SO_4$ were compared: 0, 50, 100 and 150 kg/ha. The nitrogen was applied 40% at planting, 20% at 21 days and 40% at 45 days. At planting time, 60 kg/ha of P_2O_5 as triple superphosphate, 60 kg/ha of K_2O as potassium chloride and 30 kg/ha of $ZnSO_4$ were applied.

The treatments were distributed in an incomplete block design with irrigation and nitrogen treatments replicated four times.

The experimental plots, 3.05 m × 3.05 m, were separated by earth dikes so that they could be irrigated and drained individually, and to avoid the movement of water and nutrients from one plot into another.

Mars variety was planted at the rate of 134 kg/ha November 1982 and harvested March 1983. The seed was presoaked for 24 hours before planting the water-seeded treatment.

Weeds were controlled by applying 7.0 L/ha of Propanil[4] just before permanent flooding. Insects were controlled by spraying Malathion 57% at a rate of 2.33 kg/ha. Rice brown leaf spot (*Helminthosporium oryzae* B. de Haas) was controlled by spraying with Benomyl WP at a rate of 1 kg/ha.

Weather data was recorded near the experimental site.

The "Y" leaf was taken just before flowering and analyzed for total N by the Kjeldahl method.

[4] Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment on materials.

TABLE 1.—*Effect of four nitrogen levels and three water management systems on yield of rough rice*

Nitrogen level	Dry-seeded and permanently flooded 3 weeks after planting		Pregerminated rice seeded in permanently flooded field		Dry-seeded and flooded intermittently afterwards (4 cm of water weekly)	Mean nitrogen level
kg/ha			*kg/ha*			
0	1912[1]		2434[1]	*[2]	1227[1]	1858[1]
50	1798	*	2914	*	1185	1966
100	2525		3127	*	1627	2426
150	2621		2449		1645	2238
Average of water management system	2214 AB[3]		2731 A		1421 B	

[1] Values within a column with one or more letters in common do not differ significantly at P = 0.05 according to Duncan's multiple range test.

[2] Differ significantly at the P = 0.05 between the water management systems.

[3] Values followed by one or more letters in common do not differ significantly at P = 0.05 according to Duncan's multiple range test.

Rice was harvested when about 95% of the grains had about 20% moisture; threshed and dried to 12% moisture. Yields were determined and expressed in kg of rough rice per hectare.

At harvest time, 929 cm^2 of surface area in each plot were sampled by uprooting rice plants, which were divided into grain, roots and stems, and analyzed separately for total N.

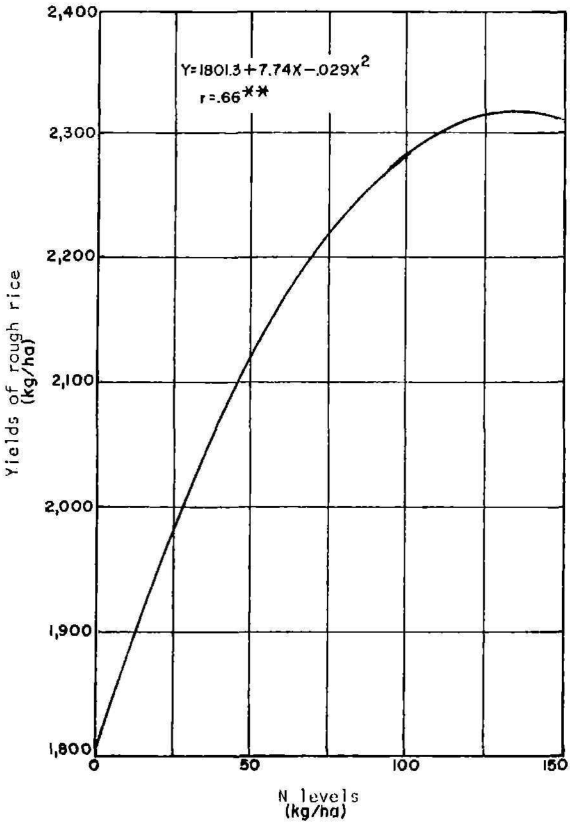

FIG. 1.—Effect of four nitrogen levels on yield of rough rice irrespective of the water management system.

RESULTS AND DISCUSSION

The water management systems had a significant effect on grain yields. The plots of pregerminated rice seeded in permanently flooded land and of dry-seeded and permanently flooded 3 weeks after planting produced higher yields than those of dry-seeded and intermittently flooded at all nitrogen levels (table 1).

Figure 1 shows that there was a close correlation between rice yields and nitrogen rates independently of the water management system. When the yield data was combined by N treatment, irrespective of the water management system, rice responded up to 125 kg/ha of nitrogen.

The nitrogen content of the leaves at flowering date was not affected by nitrogen fertilization nor by the water management system. The water management system and the nitrogen level did not have any apparent effect on panicle initiation, but flowering was delayed 12 days at 100 and 150 kg N/ha with intermittent irrigation system when compared to pregerminated rice in the permanently flooded field (table 2).

The N content of the grain was highly correlated with nitrogen levels (fig. 2). It seems that nitrogen was translocated to the grains at the beginning of flowering, because this element is vital for filling the grain. Nitrogen also induces the formation of more spikelets per panicle and increases the protein content in the grains as reported by De Datta (1).

The efficiency of the applied nitrogen as measured by the amount recovered by the plant was higher in the permanently flooded system than in the other two water management systems tested (table 3). It recovered 51%; the permanently flooded 3 weeks after planting, and the flooded intermittently systems recovered 38 and 35%, respectively.

The recovered nitrogen decreases while the nitrogen level in the permanently flooded treatment increases. The rice plants recovered 64, 49 and 39% when 50, 100 and 150 kg N/ha were applied, respectively.

TABLE 2.—*Approximate days that Mars variety took on panicle iniciation and flowering*

Treatment	Panicle iniciation				Flowering			
	N Level				N Level			
	0	50	100	150	0	50	100	150
					days			
Dry-seeded and permanently flooded 3 weeks after planting	45	45	44	44	79	79	79	79
Pregerminated rice seeded in permanently flooded field	44	44	43	43	75	75	74	74
Dry-seeded and flooded intermittently afterwards (4 cm of water weekly)	45	45	45	45	86	86	86	86

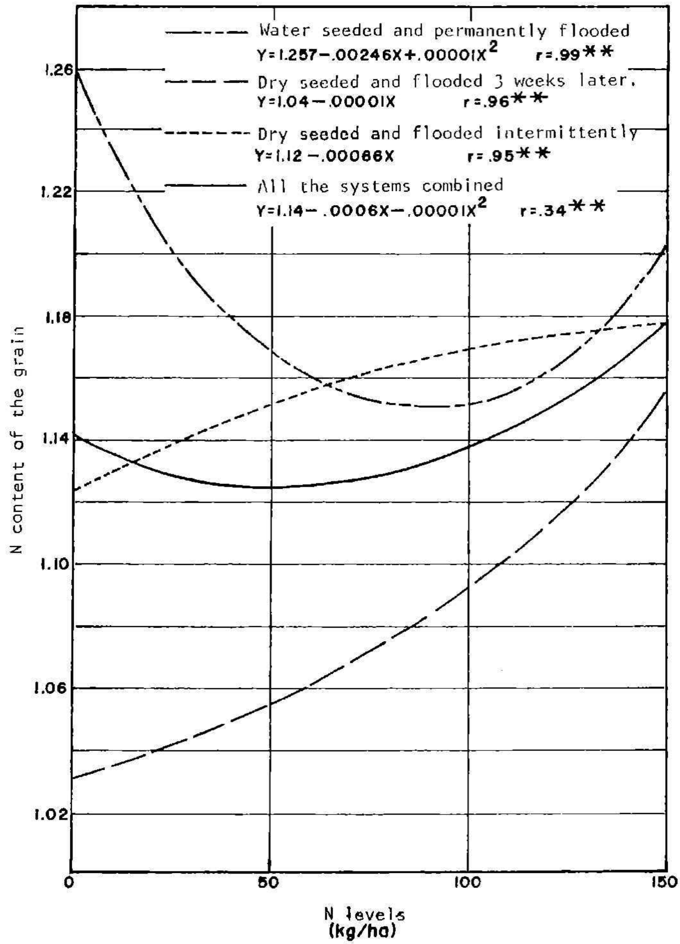

FIG. 2.—Effect of four nitrogen levels and three water management systems on the nitrogen content of the grain.

The recovery of the applied nitrogen was not affected by the quantity applied under the other two water management systems.

The largest proportion of extracted N was obtained in the stems and the lowest in the roots in all the three water management systems (table

TABLE 3.—*Effect of nitrogen levels and water management systems on the efficiency of recovery of applied nitrogen by the rice plants*

Nitrogen level	Dry-seeded and permanently flooded 3 weeks after planting		Pregerminated rice seeded in permanently flooded field		Dry-seeded and flooded intermittently afterwards (4 cm of water weekly)	Mean nitrogen level
kg/ha			*percent*			
50	37 a[1]	*[2]	64 a	*	38 a	47 a
100	41 a		49 b	*	30 a	41 a
150	38 a		39 b		38 a	38 a
Average of water management system	38 B		51 A		35 B	

[1] Values followed by one or more letters in common do not differ significantly at P = 0.05 according to Duncan's multiple range test.
[2] Differ significantly at the P = 0.05 between the water management systems.

TABLE 4.—*Effect of three water management systems on nitrogen content in stems, grains and roots of the rice plants at harvest time*[1]

Nitrogen content	Dry-seeded and permanently flooded 3 weeks after planting	Pregerminated rice seeded in permanently flooded field	Dry-seeded and flooded intermittently afterwards (4 cm of water weekly)	Mean nitrogen content
		kg N/929 cm²		
Stems	40	49	43	44
Grains	24	32	17	24
Roots	12	12	15	13
Total extracted	76 B[2]	93 A	75 B	—

[1] Average of four nitrogen levels applied.
[2] Values followed by one or more letters in common do not differ significantly at P = 0.05 according to Duncan's multiple range test.

4). The mean N content in the stems was 44, and in the roots 13 kg N/929 cm^2. Total N content in the grains varied with total yield.

Stansel et al. (12) and Sreedharan et al. (11) demonstrated that in the rainy or cloudy season light intensity decreases by 50–60% causing the response to N fertilizer to drop to half that obtained in the sunny season with high solar radiation. In Puerto Rico, season seems to have a similar effect as observed in the experiment planted in November. Yields were low compared to those obtained during the summer, probably because of shorter cloudy days, which induce a low nitrogen efficiency. Silva et al. (10) and the authors[5] found in other tests at Rio Piedras and Vega Baja, that the highest rice yields were obtained during spring and summer when seeded in dry soil and permanently flooded 3 weeks after planting.

RESUMEN

Se compararon tres sistemas de riego y cuatro cantidades de nitrógeno con respecto a la producción de arroz y la recuperación del nitrógeno aplicado.

Los rendimientos, en todas las cantidades de nitrógeno, fueron más elevadas en el sistema de inundación permanente desde la siembra y en la siembra en suelo seco e inundada permanentemente a los 21 días. El arroz respondió hasta a 125 kg N/ha al combinar los sistemas de riego.

Ni la cantidad de nitrógeno ni los sistemas de riego afectaron el contenido en nitrógeno de las hojas antes de iniciarse el espigamiento. Aparentemente, estos parámetros no afectaron la iniciación de la panoja, pero sí se retrasó 12 días más con el riego intermitente que con inundación continua desde el principio.

El contenido más elevado en nitrógeno lo tuvieron los tallos y el más bajo las raíces en todos los sistemas de riego.

La recuperación del nitrógeno aplicado disminuyó con aumentos en la aplicación de nitrógeno en el sistema de inundación permanente desde el principio. Cuando se aplicaron 50 kg N/ha se recuperó el 64%, y 39% cuando se aplicaron 150.

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